REMARKS

Applicants would like to thank the Examiner for the thorough examination of the present application. The claims have been amended to more clearly define the present invention over the cited prior art references. The claim amendments and arguments supporting patentability of the claims are presented in detail below.

I. The Claims Are Definite

The Examiner rejected dependent Claims 30 and 39 as being indefinite based upon the position that the doped P/N junction forms a bipolar transistor. Claim 30 and 39 recite that the at least one rare-earth material in the depletion layer of the doped P/N junction forms a base-collector region for a bipolar transistor. Instead of an entire transistor being formed, dependent Claims 30 and 39 recite that only the base-collector region is formed. This is discussed in greater detail on page 7, lines 9-19 in the specification, for example. In other words, the at least one rare-earth material in the depletion layer of the doped P/N junction does not by itself form a bipolar transistor, and is not part of the biasing device. Accordingly, it is submitted that Claims 30 and 39 are definite.

II. The Claims Are Patentable

The Examiner rejected independent Claims 28 and 38 over the Benton et al. patent in view of the Franzo et al. article. Alternatively, the Examiner also rejected independent Claims 28 and 38 over the Benton et al. patent in view of the Coffa et al. article; and over the Franzo et al. article in view of the Coffa et al. article. All of these

rejections will be addressed below in this section.

The present invention, as recited in amended independent Claim 28, for example, is directed to a semiconductor laser device for electro-optic applications comprising a semiconductor substrate, and a doped P/N junction integrated with the semiconductor substrate. The doped P/N junction comprises a depletion layer and has a shape defining a waveguide. The depletion layer comprises at least one rare-earth material for providing a coherent light source. The semiconductor device further comprises a biasing device connected to the doped P/N junction for reverse biasing thereof.

Independent Claim 28 has been amended to recite that all of the at least one rare-earth material remains in the depletion layer when the semiconductor laser device is operating. In addition, Claim 28 has been further amended to recite that reverse biasing of the doped P/N junction produces coherent light by pumping the at least one rare-earth material at room temperature, and the at least one rare-earth material is buried within the doped P/N junction at a depth sufficient for defining an acceleration space between a region of the doped P/N junction that generates carriers when the at least one rare-earth material is being pumped. The acceleration space allows the carriers to be accelerated before reaching the at least one rare-earth material.

Referring now to the Benton et al. patent, FIG. 3 discloses a semiconductor laser device that includes a doped P/N junction formed by layers **33** and **34**. Layer **33** includes at least one rare-earth material therein, such as erbium. As correctly noted by the Examiner, Benton et al. fails to disclose that the doped P/N junction is reversed biased.

The Examiner cited the Franzo et al. and Coffa et al. articles as disclosing this feature. Both Franzo et al. and Coffa et al. disclose the reverse biasing of a P/N junction doped with a rare-earth material, such as erbium. In particular, the doped P/N junction in these articles is for a light emitting diode (LED).

The Applicants respectfully submit that operation of a doped P/N junction as an LED which produces incoherent light is notably different than operating a rare-earth material doped P/N junction as a laser device which produces coherent light. In other words, the behavior of a rare-earth material in a doped P/N junction is very dependent on the semiconductor substrate, and the requirements to achieve laser emission are much more stringent than those to achieve an incoherent light emission as in an LED.

In the laser device of Benton et al., severe, non-radiated decay processes for erbium in silicon make it difficult to use erbium excitation by electron-hole pairs to fabricate an injection laser at room temperature. For example, in column 3, lines 44-50 of Benton et al., the disclosed laser was operated at 4.2K when data related thereto was collected. The only reference to operating the laser at room temperature is made in a generalized statement on line 50 that the collected data is expected to be substantially similar at room temperature.

Erbium excitation by hot carriers in a reverse biased P/N junction thus allows light emission to be achieved at room temperature, as disclosed in the Franzo et al. and Coffa et al. articles. However, as noted above, Franzo et al. and Coffa et al. refer to LEDs, i.e., devices in which incoherent light is generated. To obtain a coherent emission,

i.e., a laser emission, an efficient electrical excitation has to be accompanied by the inversion of the optically active ions (so that a gain can be achieved) and by a reduction of the overall losses (so that a net gain can be achieved).

These requirements can not be achieved by simply using erbium doping in a reversed biased P/N junction. The present invention thus provides an approach to meet these requirements to achieve laser action by tailoring the doping of the rare-earth material and the device structure itself in such a way to have the following conditions:

1. When the laser device is operated, all of the ions of the rare-earth material are within the depletion layer of the P/N junction. This avoids rare-earth material ions form being left outside of this region, and hence, all of the rare-earth material ions can be pumped by hot carriers which are only present in the depletion layer. It should be noted that leaving some of the rare-earth material ions outside of the depletion layer would not produce any significant effect on an LED. On the other hand, this can kill laser action since the rare-earth material ions outside the depletion layer would be left in the ground state, and hence, they would absorb, rather than amplify, the coherent light.

2. Some space needs to be left between the region of maximum electrical field in the P/N junction (where the carriers are generated) and the depletion layer comprising the rare-earth material. This space allows proper acceleration of these carriers before they reach the ions of the rare-earth material. For example, 0.8 eV is needed to excite a erbium ions from the ground state to the first excited state.

Failing to meet this condition will produce a dark region in the center of the depletion layer, where erbium ions will not be pumped since the energy of the carriers will not be sufficient. Once again, these erbium ions would be left in the fundamental state and will absorb, rather than amplify, the coherent light.

As recited in amended independent Claim 28, the at least one rare-earth material is buried within the doped P/N junction at a depth sufficient for defining an acceleration space between a region of the doped P/N junction that generates carriers when the at least one rare-earth material is being pumped. The acceleration space allows the carriers to be accelerated before reaching the at least one rare-earth material.

3. The claimed invention also makes use of the fact that acceleration of the carriers to the depletion layer allows efficient pumping of the rare-earth material even at room temperature.

The Applicants respectfully submit that even if the references were combined as suggested by the Examiner, the claimed invention is still not produced based upon the above discussions. Accordingly, it is submitted that amended independent Claim 28 is patentable over Benton et al. in view of the Franzo et al. article, and alternatively, in view of the Coffa et al. article. Independent Claim 38 has been amended similar to independent Claim 28. It is also submitted that independent Claim 38 is patentable over the prior art references.

In view of the patentability of amended independent

Claims 28 and 38, it is submitted that their dependent claims which recite yet further distinguishing features of the invention are also patentable. These dependent claims need no further discussion herein.

CONCLUSION

In view of the amendments to the claims and the arguments provided herein, it is submitted that all the claims are patentable. Accordingly, a Notice of Allowance is requested in due course. Should any minor informalities need to be addressed, the Examiner is encouraged to contact the undersigned attorney at the telephone number listed below.

Respectfully submitted,

MICHAEL W. TAYLOR
Reg. No. 43,182
Allen, Dyer, Doppelt, Milbrath
& Gilchrist, P.A.
255 S. Orange Avenue, Suite 1401
Post Office Box 3791
Orlando, Florida 32802
407/841-2330